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CURLY-TOP-RESISTANT SUGAR-BEET VARIETIES IN 1938[1]

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INTRODUCTION

The use of curly-top-resistant varieties of sugar beets has removed much of the danger that formerly threatened destruction of the beet-sugar industry in parts of California, western Colorado, Idaho, and Utah. The industry in these States has been revived and stabilized. Sugar-beet growing has also been resumed on a large scale in areas in California, Idaho, Oregon, and Washington from which curly top earlier drove it out. A beet-sugar factory was built in the Yakima Valley of Washington at Toppenish in 1937 on the site of a factory abandoned in 1924. At Nyssa, Oreg., a plant has been constructed to serve western Idaho and eastern Oregon. Near Delta, Utah, where a beet-sugar factory was abandoned in 1924, several fields of sugar beets were successfully grown in 1937 and the acreage will be expanded in 1938. In the San Joaquin Valley of California, where two factories earlier failed, an extensive acreage was planted in 1937 and in 1938 plantings were increased.

HISTORY OF CURLY-TOP-RESISTANT VARIETIES

Curly-top control to the degree indicated began with the release of the resistant variety U. S. 1.[2] This variety was damaged severely by drastic curly-top exposure because it consisted largely of individual

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[1] Cooperation of the Curly Top Resistance Breeding Committee, an organization representing all the sugar companies operating in curly-top areas, has accelerated progress in the breeding program by making adequate seed supplies of new varieties promptly available and by making large-scale agronomic evaluation possible. Tests at Davis and Riverside, Calif., were conducted in cooperation with the California Agricultural Experiment Station. The Utah Agricultural Experiment Station and the University of Idaho Agricultural Experiment Station cooperated in varietal tests at Logan, Utah, and Aberdeen, Idaho.

[2] CARSNER, EUBANKS, and others. CURLY-TOP RESISTANCE IN SUGAR BEETS AND TESTS OF THE RESISTANT VARIETY U. S. NO. 1. U. S. Dept. Agr. Tech. Bull. 360, 68 pp., illus. 1933.

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plants only moderately resistant, but resistance in the variety averaged high enough to give a great advance toward satisfactory curly-top control. In one outstanding test, the average yield of U. S. 1 was 13.6 tons per acre, while R. & G. Old Type, a variety then extensively used in that area, gave an average yield of 2.5 tons per acre in this same trial. Sucrose percentage in the variety was of acceptable quality.

In addition to having only an intermediate degree of curly-top resistance, U. S. 1 bolted too readily to be suitable under conditions conducive to bolting, particularly with fall and winter planting in California.

U. S. 1 has since been superseded by varieties that are more resistant to curly top.[3] This next forward step was accomplished by use of U. S. 34 and A–600, the latter a variety developed by the Amalgamated Sugar Co. U. S. 33 quickly followed.

None of these varieties satisfactorily met the differing requirements of all localities in which curly-top-resistant varieties are needed. Further breeding work was therefore encouraged. This circular reports another step toward the goal of varieties adapted to regions where curly top is an important factor.

SOURCE OF EXTREME RESISTANCE

An important feature of U. S. 1 was that a very small proportion of individuals comprising the variety were extremely resistant to curly top. The source of this extreme resistance is not known with certainty, but it seems likely that it originated by accidental hybridization with wild beets. The evidence now indicates that in the early breeding work [4] such hybridization with wild beets occurred. Selected mother beets were isolated in places in southern California and progenies from these appeared as if they had been hybridized with wild types. Subsequently, hybrids between wild species and cultivated beets were discovered growing wild [5] in the same area in southern California. Presumably, accidental hybridization between a selected mother beet and these wild types gave rise to a progeny that was highly resistant to curly top and known as 286. Strain 286 resembled wild beets in root type and bolting tendency and was extremely low in sugar. For these reasons 286 was not included in the parentage of the U. S. 1 variety. However, some accidental hybridization of the parental strains of U. S. 1 and progenies comparable in origin with 286 is now suspected. The possibility of getting extreme resistance from wild forms is indicated by the fact that Coons, Stewart, and Elcock [6] discovered extreme resistance in forms of *Beta maritima* L. collected in Europe and recovered this resistance after hybridizing with susceptible commercial sugar beets.

The occurrence of extremely resistant individuals in U. S. 1 made that variety highly valuable as a source for further selection. Selection of very resistant individuals from U. S. 1 has given rise to a number of extremely resistant strains. U. S. 12 was thus originated by mass selection.

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[3] [UNITED STATES] BUREAU OF PLANT INDUSTRY, DIVISION OF SUGAR PLANT INVESTIGATIONS. NEW SUGAR-BEET VARIETIES FOR THE CURLY-TOP AREA. U. S. Dept. Agr. Cir. 391, 5 pp., illus. 1936.

[4] CARSNER, EUBANKS. RESISTANCE IN SUGAR BEETS TO CURLY TOP. U. S. Dept. Agr. Dept. Cir. 388, 8 pp., illus. 1926.

[5] The wild beets in California are believed to have been introduced as hybrids of the type indicated with seed from Europe.

[6] COONS, G. H., STEWART, DEWEY, and ELCOCK, H. A. SUGAR-BEET STRAINS RESISTANT TO LEAF SPOT AND CURLY TOP. U. S. Dept. Agr. Yearbook 1931: 493–496, illus. 1931.

RESISTANT VARIETIES

U. S. 12

High curly-top resistance is the distinctive feature of U. S. 12 (fig. 1). It is much better in this respect than U. S. 33 or U. S. 34 and, consequently, gives higher yields under heavy curly-top exposure. For curly-top-resistance it may be placed in the same general class as A–600. Near Buhl, Idaho, in 1936, under curly-top exposure which caused failure of a susceptible variety and reduced the acre yield to 3.06 tons, the acre yield of U. S. 12 was 20.14 tons and of U. S. 33 was 18.11 tons. This was on soil of relatively good fertility. In the same district in 1937, but with lower soil fertility and half of the planting purposely delayed a month to increase curly-top severity, U. S. 12 yielded 10.52 tons per acre as compared with 7.09 tons for U. S. 33 and 1.60 tons for R. & G. Old Type. A yield of 10.52 tons per acre under such circumstances is encouraging.

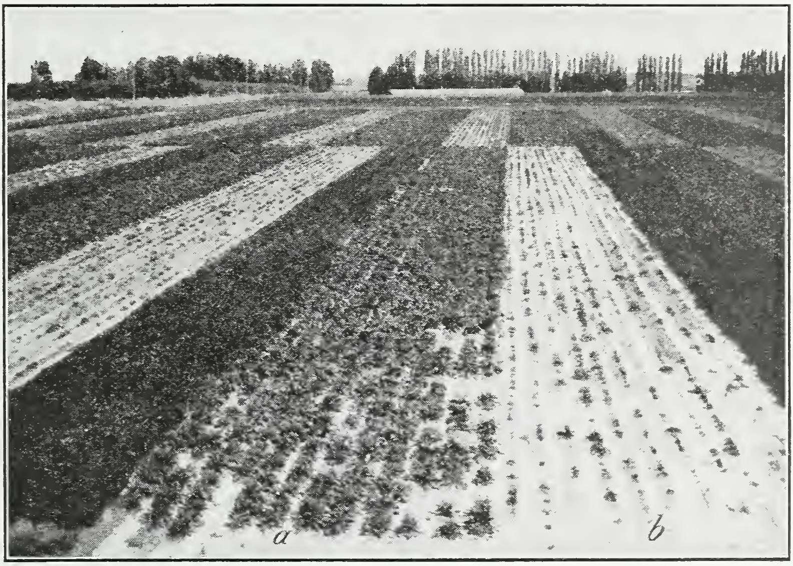

FIGURE 1.—U. S. 12 (*a*) and R. & G. Old Type (*b*) under extreme curly-top exposure near Buhl, Idaho, in 1937. Buffer strip of Red Mexican beans on each side. Plots in spraying experiments conducted by the University of Idaho Agricultural Experiment Station and Bureau of Entomology and Plant Quarantine, United States Department of Agriculture. Photographed August 19, 1937, by J. R. Douglass, Bureau of Entomology and Plant Quarantine.

Sucrose percentage in U. S. 12 is equal or superior to that of U. S. 34 or A–600 and most of the highly resistant strains with which it has been compared, but inferior to that of U. S. 33. Sucrose percentage was low in the first extremely resistant strains discovered[7] and the possibility of combining high sugar content with extreme resistance had not been proved when U. S. 1 was released.[8] U. S. 12 demonstrates that such a combination is possible.

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[7] CARSNER, EUBANKS. See footnote 4, p. 2.
[8] CARSNER, EUBANKS, et al. See footnote 2, p. 1.

The bolting tendency in U. S. 12 is more nearly uniform and slightly lower than in U. S. 33 and U. S. 34. Spring planting of U. S. 12 in Utah, Idaho, Oregon, Washington, and California has shown little or no bolting, in contrast to spring planting of U. S. 33 and U. S. 34, which usually have at least a few seedstalks in evidence. U. S. 12 is not to be considered a variety low in bolting tendency, however, because it will bolt strongly under some conditions under which beets are grown for sugar. Fall and winter plantings in California have resulted in as much bolting in U. S. 12 as in U. S. 33.

The performance of U. S. 12 was compared with other varieties under a number of different conditions and results are given in tables 1 to 4.

TABLE 1.—*Variety tests under severe curly-top exposures, Buhl, Idaho, 1935–37* [1]

Variety	Seed lot No.	Acre yield		Sucrose	Apparent coefficient of purity	Plants showing curly top, July 28
		Indicated available sugar [2]	Beets			
FROM L. ROUBINEK FIELD—PLANTED, APR. 22; HARVESTED, OCT. 25, 1935						
		Tons	*Tons*	*Percent*	*Percent*	*Percent*
A-600		3.111	21.39	16.30	89.37	
Parent of U. S. 12	3409	2.953	19.22	17.05	90.23	
U. S. 34		2.757	17.32	17.32	91.65	
U. S. 33		2.705	16.21	18.10	92.44	
U. S. 14	3403	2.312	14.44	17.47	91.66	
Check	40	.539	3.60	16.66	89.88	
Difference for 19:1 odds [3]		[4].284	[4]1.70	[4].62	[4]1.50	
FROM L. ROUBINEK FIELD—PLANTED, APR. 30; HARVESTED, OCT. 12–17, 1936						
U. S. 12	518	2.958	20.14	16.51	88.80	25
U. S. 33	5642	2.741	18.11	16.97	88.11	53
A-600	5647	2.661	19.29	15.78	87.36	38
U. S. 34	5641	2.602	18.43	16.14	87.18	50
U. S. 34	5650	2.571	18.70	15.69	87.84	50
U. S. 1	0137	1.958	13.37	16.51	88.74	79
Check	40	.414	3.06	14.80	91.47	100
Difference for 19:1 odds [3]		[4].426	[4]2.57	.80	2.11	
FROM S. D. BONAR FIELD—PLANTED, ONE-HALF, APR. 9; ONE-HALF, MAY 6; HARVESTED, OCT. 8–14, 1937						
U. S. 12	618	1.718	10.52	17.92	91.18	28
U. S. 33	5642	1.178	7.09	18.01	92.37	92
R. & G. Old Type	5638		[5]1.60			100
Difference for 19:1 odds [3]		[4].248	[4]1.65	.44	1.40	

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[1] Data are taken from averages of 6 replicated plots in 1935, from 7 replicated plots in 1936, and from 12 replicated plots in 1937.

[2] Indicated available sugar was obtained by multiplying tons of beets by percentage of sucrose and purity coefficient and dividing by 100^2.

[3] The difference for 19:1 odds is taken as twice the standard error of mean difference.

[4] Indicates significant differences between varieties.

[5] Yield for R. & G. Old Type estimated from strips adjacent to replicated plots of the other varieties.

TABLE 2.—*Variety test under medium curly-top exposure under 2 fertility gradients, Granger, Utah, 1936–37*

Variety	Seed lot No.	Acre yield		Sucrose	Apparent coefficient of purity
		Indicated available sugar [1]	Beets		
		Tons	*Tons*	*Percent*	*Percent*
NORMAL FERTILITY, 1936—PLANTED, APR. 13: HARVESTED, OCT. 28					
U. S. 33	5642	3.594	22.89	17.88	87.94
U. S. 12	518	3.568	22.69	17.86	88.14
A-600	5647	3.456	22.97	17.21	87.47
U. S. 34	5641	3.452	23.39	17.08	86.56
Difference for 19:1 odds [2]		.269	1.45	[3] .27	1.71
EXTRA HIGH FERTILITY, 1936—PLANTED, APR. 13; HARVESTED, OCT. 28					
U. S. 33	5642	3.104	23.15	16.03	83.74
U. S. 12	518	2.942	23.43	15.36	81.56
U. S. 34	5641	2.942	22.59	15.63	83.39
A-600	5647	2.940	26.23	14.08	79.68
Difference for 19·1 odds [2]		.227	[3] 1.60	[3] .82	[3] 1.82
AVERAGE OF FERTILITY SECTIONS, 1936					
U. S. 33	5642	3.349	23.02	16.96	85.84
U. S. 12	518	3.255	23.06	16.61	84.85
A-600	5647	3.198	24.60	15.65	83.58
U. S. 34	5641	3.197	22.99	16.35	84.98
R. & G. Old Type	5638		[4] 20.00		
Difference for 19:1 odds [2]		.177	[3] 1.23	[3] .58	[3] 1.27
AVERAGE OF FERTILITY SECTIONS, 1937—PLANTED, APR. 13; HARVESTED, OCT. 28					
U. S. 12	618	3.235	23.67	15.52	87.88
U. S. 33	5642	3.194	22.14	16.13	87.14
R. & G. Old Type	5638		[4] 10.00		
Difference for 19:1 odds [2]		.211	.95	[3] .59	1.76
AVERAGE FOR 1936 AND 1937					
U. S. 33	5642	3.271	22.58	16.55	86.49
U. S. 12	618	3.245	23.37	16.07	86.37
Difference for 19:1 odds [2]		.203	1.09	.59	1.56

[1] Indicated available sugar was obtained by multiplying tons of beets by percentage of sucrose and purity coefficient and dividing by 100^2.

[2] The difference for 19:1 odds is taken as twice the standard error of mean difference.

[3] Indicates significant differences between varieties.

[4] Yield for R. & G. Old Type estimated from strips adjacent to replicated plots of the other varieties.

Table 3.—*Variety test under light curly-top exposure, Twin Falls, Idaho,*[1] *and King City, Calif.,*[2] *1936*

TWIN FALLS, IDAHO

Variety	Seed lot No.	Acre yield: Indicated available sugar[3]	Acre yield: Beets	Sucrose	Apparent coefficient of purity
		Tons	*Tons*	*Percent*	*Percent*
U. S. 12	518	3.631	24.86	15.94	91.64
U. S. 34	5650	3.433	24.79	15.19	90.59
U. S. 33	5642	3,413	23.11	15.91	92.71
A–600	5647	3.301	23.55	15.35	91.28
U. S. 34	5641	3.296	23.94	14.94	92.10
R. & G. Old Type	5638	3.447	24.28	15.43	91.99
Difference necessary for 19:1 odds[4]		[5].340	[5]2.05	[5].62	[5]1.39

KING CITY, CALIF.

Variety	Seed lot No.	Acre yield: Indicated available sugar[3]	Acre yield: Beets	Sucrose	Apparent coefficient of purity
U. S. 33	5642	4.498	24.17	20.55	90.88
U. S. 34	5641	4.462	24.79	19.96	90.77
U. S. 12	518	4.398	24.05	20.25	90.52
U. S. 14	515	4.361	24.76	19.69	90.09
R. & G. Old Type	5638	3.665	20.75	19.69	89.87
Difference necessary for 19:1 odds[4]		[5].333	[5]2.088	[5].532	1.24

[1] Data are taken from the averages of 8 replicated plots, each 4 rows wide and 50 feet long.

[2] Data taken as average from 8 replicated plots of each variety; plots 4 rows wide and 65.5 feet long. Planted Mar. 17, 1936; harvested Oct. 17, 1936.

[3] Indicated available sugar was obtained by multiplying tons of beets by percentage of sucrose and purity coefficient and dividing by 100^2.

[4] The difference for 19:1 odds is taken as twice the standard error of mean difference.

[5] Indicates significant differences between varieties.

Table 4.—*Variety tests with regard to bolting* [1]

Location of test	Date of planting	Date of bolter count	U. S. 12, first increase seed lot No. 618	U. S. 33: Original seed lot No. 3407	U. S. 33: Second increase seed lot No. 5642	U. S. 14: First increase seed lot No. 515	U. S. 14: Second increase seed lot No. 617	R. & G. Old Type from European seed lot No. 5638
			Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Granger, Utah	Apr. 13, 1937	Aug. 1, 1937	0.06		0.40			
Salinas, Calif	Dec. 22, 1936	May 27, 1937	21.00	11.00	25.00	6.00	11.00	4.00
Davis, Calif	Dec. 23, 1936	June 10, 1937	70.00	56.00	63.00	27.00	65.00	24.00
Riverside, Calif	Oct. 23, 1936	Apr. 22, 1937	35.00	11.00	41.00	.30	1.70	.40
Do	do	May 18, 1937	64.00	41.00	73.00	4.00	16.00	4.00

[1] Data for these bolting counts in California were taken from strip plantings instead of replicated plots and are, therefore, subject to considerable experimental error. The results from 2 strips, each 200 feet long, were averaged together for the Riverside test, while single strips were used at Davis and Salinas with alternate check rows of R. & G. Old Type for comparison. In general, the differences in bolting were so striking that these rough measurements are considered sufficiently accurate.

U. S. 12 originated from 33 choice plants, selected for extreme resistance out of U. S. 1, near Twin Falls, Idaho, in 1931. Progeny of this group was tested in 1933 and a reselection of 69 plants was made. The seed resulting from these reselected plants was increased in 1935 near Salt Lake City, giving a yield of 493 pounds. An increase for stock seed amounting to 28,570 pounds was then made at St. George, Utah, in 1936. This supply of stock seed made possible commercial increases in the seed-growing areas of Arizona, California, New Mexico, and Utah, so that the 1937 seed production of this variety was approximately 2,551,000 pounds. U. S. 12 was therefore planted extensively for sugar production in 1938.

U. S. 14

U. S. 14 has received special attention because it is a curly-top-resistant variety that has low bolting tendency. A variety of this type is needed for winter planting in California. Curly-top resistance in U. S. 14 is not high, about as in U. S. 1, but is high enough to give good results where curly-top exposure is moderate. The variety is rather susceptible to downy mildew and, therefore, is subject to severe damage by this disease when planted early in areas where downy mildew occurs, especially in California coastal districts. Probably U. S. 14 will be used to only a limited extent and soon will be replaced by better varieties.

U. S. 14 was derived from strain 5001, one of the parental strains combined to produce U. S. 1. Some increase in the bolting tendency of U. S. 14 has resulted from seed production in a mild climate (table 4).

U. S. 33

U. S. 33 has been described before [9] but requires further consideration. The variety has now been more extensively evaluated in agronomic tests and has been used widely in commercial plantings.

Irregularity in bolting tendency characterized the original stock and some deterioration in this regard has resulted from repeated reproductions in mild climates. Until the variety is markedly improved in bolting tendency, it will continue unsuitable for winter planting in California.

Curly-top resistance is not extremely high in U. S. 33, but with fair to high soil fertility the variety gives good yields in sugar per acre, even under relatively severe curly-top exposure. Sucrose percentage is consistently higher in U. S. 33 than in any curly-top-resistant variety now available, and the variety performs well under a wide range of conditions.

U. S. 33 will continue in extensive use and efforts are under way to improve it. A planting of the original seed in September 1937, under conditions favorable to maintaining quality, has given stock seed superior to any heretofore available.

GOOD CULTURAL PRACTICES IMPORTANT

Even though good varieties are now available, and others are being developed, emphasis needs to be placed on the fact that curly-top resistance alone will not give the best results. After varietal adaptation to a given locality has been accomplished, the best results will be obtained by careful attention to time of planting, soil fertility, and cultural care.

Early planting is usually advantageous, provided the bolting tendency of the variety involved is not a limiting factor. Bolting tendency is too strong in U. S. 33 and U. S. 12 to permit fall and winter planting of these varieties in California. U. S. 14 can be planted somewhat earlier than U. S. 33 and U. S. 12.

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[9] [UNITED STATES] BUREAU OF PLANT INDUSTRY, DIVISION OF SUGAR PLANT INVESTIGATIONS. See footnote 3, p. 2.

BOLTING AND SEED PRODUCTION

Bolting is undesirable always when beets are being grown for sugar. Marked reduction in acre yield of sugar results where percentage bolting runs high, as it sometimes does with fall and winter plantings in California. Where bolting ranges from a trace to 5 percent it may not significantly influence yields, but even in small amount it is objectionable because of detracting from the appearance of the fields. Bolting is also objectionable when seed matures and is allowed to scatter on the soil.

Bolting is, of course, necessary for seed production, and seed growing by the method of planting in early fall and overwintering the crop in the field is practicable in relatively mild climates with varieties that bolt readily. U. S. 1 had a strong bolting tendency and great impetus was given a new industry by growing seed of this variety in southeastern New Mexico, southwestern Utah, and southern California. This industry has since expanded into southeastern Nevada and southern Arizona. U. S. 34, U. S. 33, and now U. S. 12 produce large seed yields in these areas, because they also are rather easily induced to bolt.

Varietal differences in bolting tendency and irregularity in this regard within varieties complicate seed production. Yields of seed in mild climates are not so good with varieties low in bolting tendency, such as U. S. 14, and, in such cases, because the seed is produced by individual plants that bolt more readily, deterioration or increase of bolting tendency results. U. S. 33 suffers in this way because sometimes 20 percent or more of its component types remain vegetative, or bolt too late to participate in the seed crop. The original stock of U. S. 33 planted at Salinas, Calif., on December 20, 1936, developed 11 percent of bolters by May 27, 1937, whereas the same variety, after two generations in mild climates, had 25 percent of bolters in the Salinas test. This and other comparisons are shown in table 4.

Washington County, Utah, normally has colder winters than any of the seed-growing areas mentioned, but varietal differences in bolting tendency, as between U. S. 12 and U. S. 14, appear there as the differences in rate of development shown in figure 2 indicate.

Seed production in relatively mild climates can be continued without seriously increasing bolting tendency, provided stock seed grown in relatively cold areas is used each year. Better suited areas must be used for seed production of all varieties low in bolting tendency. Central Utah regions in the vicinity of Salt Lake City and southern Idaho districts near Twin Falls have been tested in this connection with encouraging results. Certain districts in northern California and western Oregon seem especially well adapted climatically. Extensive exploratory tests and some commercial plantings have been conducted in that area by the West Coast Beet Seed Committee, a commercial organization, under the management of George T. Scott.

The outlook for the domestic sugar-beet-seed industry is that the method of overwintering in the field can be widely enough adapted to meet all requirements.

OTHER VARIETIES BEING DEVELOPED

Curly-top-resistant varieties superior to those now in use are being tested. The varieties found by critical evaluation to be best adapted will be multiplied and later made available for use in the areas to which they are best suited. Some of the new varieties combine curly-top resistance and a degree of downy-mildew resistance which encourages the hope that breeding for downy-mildew resistance will afford a control for that disease.

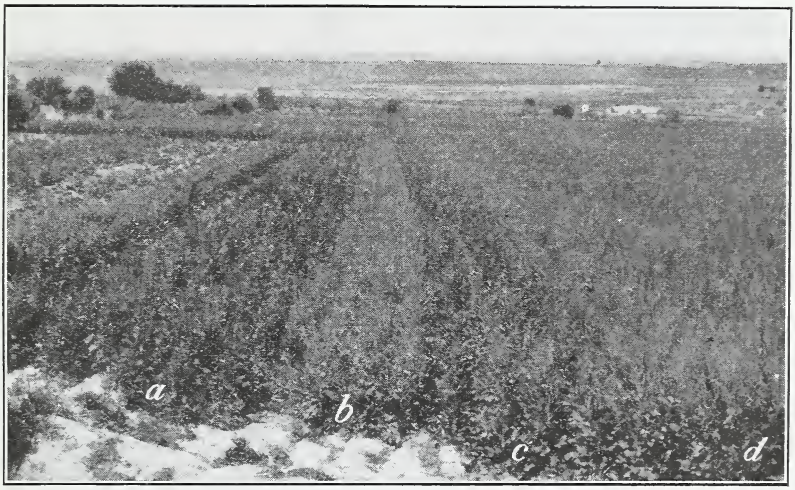

Figure 2.—Field of sugar-beet varieties at St. George, Utah, planted September 14, 1935, illustrating differences in seed production in relatively mild climate caused by the tendency of different varieties to vary in rate and amount of bolting: *a*, U. S. 14; *b*, U. S. 12; *c*, 550; and *d*, U. S. 34. Photographed May 7, 1936.

Curly-top-resistant varieties have been in use only a few years and there has been a rapid succession of varieties. U. S. 1 was released to meet an emergency and was widely used, even though imperfections in it were recognized. U. S. 33, U. S. 34, and A–600 were better in some respects than U. S. 1 and soon replaced it. Now that U. S. 12 and U. S. 33 have reached the dominant position for the major part of the curly-top area and probably will be found reasonably well adapted, their replacement with new varieties may be more deliberate. Present plans, therefore, involve extensive testing of new varieties under consideration before any are chosen for release and widespread distribution. This procedure will afford better protection against disappointing results and will avoid the confusion which arises when many varieties are in use at the same time.

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